THE BEE

THE HALLWAG POCKET LIBRARY

nitowr According to the Acc. Regigster the Acc'
No. should be

(4262) because the

~~4261~~ no. 4261 put down
n this book is for another
book

THE HALLWAG POCKET LIBRARY

THE BEE

by

GERTRUD HESS

EDWARD STANFORD LIMITED
12–14, Long Acre, London, W. C. 2

THE HALLWAG POCKET LIBRARY

NO. 4

THE BEE

GERTRUD HESS

Translated from the German by W. Gossling

Plates and printing by Hallwag Limited, Berne
PRINTED IN SWITZERLAND

The Honey-bee

It has been established that the earth has a million different kinds of animal inhabitants, including Man.

Three quarters of these are insects.

Out of 750,000 kinds of insect, man has chosen two for domestication because their products are of use to him: these are the Silkworm and the Honey-bee.

This little book is about the Honey-bee, which has yielded man profit since ancient times. Through centuries of practical cultivation and recent intensive research, the bees have become one of the best-known members of creation and have remained unchanged. Their power of learning is too slight and they are ruled completely by their instincts, so that no outside influence can affect them. When wild bees find a suitable shelter, they will in favourable circumstances carry on their existence without any help from Man, just as they did ten thousand years ago, when no men were taking any interest in them.

In consequence, we find that the technique of bee-keeping has certain limits, which is all part of its charm. Here man challenges Nature. He can exert no force or compulsion on the bees and he has to acknowledge their individuality and respect their laws if he wants to make any profit from them.

Thus bee-keeping is a fascinating kind of trial of wits with Nature, carried on as much for its own sake as for its sweet reward.

Historical

There is in Spain a cave-drawing dating from the Old Stone Age, which proves that the honey of wild bees was already known in the oldest phase of history. This drawing shows a human figure standing on a rope ladder, evidently just taking the honeycomb out of a hole in the rock where the wild bees have built a nest. One hand is in the hole, and the bees are swarming all around, while the other hand holds a vessel ready for the honeycomb.

Such an early interest in bees is not surprising if we consider that honey is a ready-made sweet stuff, a concentrated and practically pure solution of sugar. As long as sugar was still rare and of course expensive, man made use of honey for sweetening purposes.

The Indians of ancient times already knew how to make use of the sugar-cane, but though the sugar produced from it was also known in the West at the time of Alexander the Great, it still remained a rare product until recently. For this reason honey was used for a long time for sweetening food, and now, since the introduction of the cheaper beet-sugar, it is mostly regarded as a luxury.

Formerly wax as a raw material was at least as important as honey. As the process of getting the honey meant cutting out and destroying the comb, wax began to be collected for its own sake.

We must assume that the moulds of the bronze age were made by the lost wax method. Beeswax was also used as a cement for fixing spearheads to shafts.

The first real information about bees and bee-keeping comes from the Egyptian royal tombs. According to the texts and pictures found in these, the ancient Egyptians must have kept bees five or six thousand years ago. They had clay vessels laid one on top of each other, the ones containing the honeycomb were in flat vessels but the liquid honey was kept in deep well-sealed amphorae. The high estimation in which bees were held in Egypt is also demonstrated by the hieroglyphics where a bee is used to represent a king. The Old Testament and Homer in comparison must be regarded as relatively recent testimonies of an ancient bee-culture in the Eastern Mediterranean.

In Classical Antiquity according to Greek and Roman writers, the practice of bee-keeping was widespread among rich and poor, and had already reached a high standard even then. Beeswax had become of more importance as a working material. The ancient tablets made out of wax are well known. It was also used for pharmaceutical purposes and in cosmetics, but to-day paraffin-wax has replaced it in the manufacture of high class products.

Honey and mead are frequently mentioned in the Northern Sagas.

The Romans also tell us that at the time when their legions were advancing into the North, the Germans already knew about bee-keeping. While the civilised Romans possessed woven-straw hives and block hives, made from sections of hollowed tree trunks, and even a third type made out of baked clay, and the Greeks already had the idea of movable combs, bee-keeping in the Northern lands was not so far advanced. In Western Europe the woven-straw hive or skep seems to represent the earliest type. Indeed it is still to be found to-day in remote places. In the forest lands of Eastern Europe the block hive is the usual one and may be seen set up on the ground or hanging from a tree.

Further evidence of the veneration of bees on the northern side of the Alps is afforded by the tomb of Childerich I. When it was opened in 1635, a purple mantle was found there and the trappings of his horse which was buried with its master. Embroidered on these cloths were three hundred golden bees. Napoleon also ornamented himself and his 'eagles' in the same fashion.

In early times a symbol of the immortal kings, bees to-day are regarded only as the emblem of industry.

Because bees under Man's protection do not allow themselves to be influenced in any way in their habit of life, one finds primitive and highly specialized bee-keeping going on side by side even at the present time. In Egypt for instance, bee-hives made out of dried mud from the Nile are still used to some extent; in Eastern Europe and in Africa there is a kind of bee-culture in which the honey is taken away from the wild colonies, but an increase is encouraged by the cutting out of a sufficient number of holes in the trees.

However, the modern bee-keeper seeks to stimulate honey production; on the one hand he tries to save the bees as much trouble as possible: he provides them with necessary food, he helps them survive the winter, he renews the combs and so on. On the other hand he controls their industry, which is the manufacture of honey.

The Bee-hive

The modern bee-hive, as most people know, is a wooden structure like a large box with equal sides and a movable roof, the whole standing on four legs. In front, it has an entrance hole at the bottom and an alighting board for the bees, sloping down slightly from the entrance. Inside, there are two storeys of frames holding comb, one containing brood below and then a 'super' above, for the storage of honey.

The most important contrivance in the economy of bee-keeping is the movable comb. These were probably used in some form even in ancient times, but it is only one hundred and fifty years since the idea was put into general practical use; the modern type is the result of a discovery made by François Huber, the blind savant of Geneva.

There are various types of bee-hives, but what they all have in common is, that they induce the bees to build their combs in wooden frames; the ends of these project slightly and rest on two narrow shelves so that they can be moved along. According to the type of hive, for hot or cold climates the frames hang either parallel or perpendicular to the entrance. Short nails hold the combs on the frames at the right distance from one another. This distance must correspond to the width of the alley-way in a wild bees' nest, which is about half an inch. By using movable combs it is possible for the bee-keeper to control his colonies: he can add a comb or take one away without disturbing the bees too much, and that is particularly convenient when it comes to the honey-harvest.

As bees always lay up a store of honey above the brood-nest, we hang the combs in two storeys during the summer. They mostly use the lower and larger comb for the brood and fill the upper smaller combs with honey. The latter can then be taken away when the honey is ready, without much interference from the bees.

The Usefulness of Bees

Man's first interest in bees was due to their honey, and they are still prized now for the same cause.

The gifts of creation are ranked by Man according to their use or their danger, and bees are given a high place. We forgive the bees their sting for the sake of their honey, but their greatest value does not rest so much on the production of honey, as in the circumstance, that in visiting flowers for nectar, they also pollinate them. Because they bring about the setting of fruit-blossom, the keeping of bees is worth while for this alone, and their use in this way really surpasses the value of the honey-crop ten times over.

Of course, we know that there are other insects which visit flowers, such as the many solitary bees, the humble-bees, butterflies, certain flies and several beetles. But none of these is of much consequence for efficient pollination, as we owe a good three quarters of the fruit crop to the activities of the honey-bee alone. There are a number of facts to prove this. First, bees pass the winter as large colonies of individuals and begin the spring with thousands of foraging bees, at a time when other insects have not yet begun to reproduce; and when even humble-bees are only slowly beginning to build up a small community. Then also, bees work more industriously than other insects because they not only procure the necessary food for their young but also lay up considerable stores of honey. A bee colony is able to visit over five million flowers in the course of a day. In addition, as is evident without further observation, bees are 'flower-constant', that is they collect nectar or pollen as long as possible from the same kind of flower. In this way they carry pollen from one apple

Bee returning home with pollen baskets

blossom to another or pollen from one flower of Meadow-Sage to the next and so bring about pollination which produces fruiting. Bees usually come home with 'pollen-stockings' of one colour; golden yellow from hazels, sulphur-yellow from apple blossom, orange-yellow from dandelions, red from dead-nettles and so on. But humble-bees on the other hand may be seen mostly with variegated stockings, as they seem to collect their nectar from different kinds of plants that happen to be growing near one another. A thorough pollination not only favours an increase in the crop but also stimulates full development of the individual fruits. It has been proved that well-pollinated flowers produce more perfect fruits because there is enough pollen for all the ovules to develop into seeds.

In addition to fruit, other cultivated crops are pollinated by the agency of bees, for example, many different berries, vines, cucumbers and beans. Other vegetables and many flowers need to be pollinated by bees to ensure seed-production. We can therefore understand why bee-keeping is of such general importance, and why, for example, the Swiss Federation has even passed laws for the benefit of bees. One of these forbids the picking of hazel and willow catkins. These shrubs offer the earliest supply of pollen at a time when other plants are still in bud.

Pollen provides the necessary protein for the young brood. If a good store of pollen has not been gathered from the end of February to the end of March, there will be a lack of foragers in April and May at the time of the fruit-blossom.

Temperature in the Colony

We have seen how much depends on the bees' diligent visits to flowers, and now the question arises, why should bees collect more honey than they can easily consume? The answer is that bees store up a winter supply because they pass the winter as a colony, instead of becoming inactive as individuals like other insects.

It is true that ants also winter as a colony but they all remain inert in the depths of their nest. In the case of humble-bees and wasps, the workers die when the first frost comes, and only the queens survive by hiding themselves in a sheltered place, so that they are able to produce a new colony in the following spring. Honey-bees on the other hand, during the cold weather, will be found on their combs, sitting tightly packed together, eating their stores and burning it up in their bodies. In this way they keep warm. However far below zero the outside temperature falls, one always finds that in the winter cluster a temperature of 68–86° F. can be measured.

The regulation of temperature stops where the outermost bees form the 'skin' of the cluster. In order that these bees may not become torpid, the temperature outside must not be below 48° F. In consequence the production of heat in the winter cluster rises and falls in the opposite direction to the temperature outside the hive.

For insects to have a constant temperature is something out of the ordinary because as a class they are cold-blooded, having a fluctuating temperature like most other animals except birds and mammals. Their temperature is the same as the outside temperature. If this is high, then their body temperature is high and they are correspondingly lively; but if the temperature falls, they become chilled and finally quite inert.

On a summer's day in the mountains we can see how very dependant the insects are on the temperature of their surroundings. In that cool air there is noise and movement over the flowering meadows only when the sun is shining. If a cloud passes over, all is silent at once; the insects drop down among

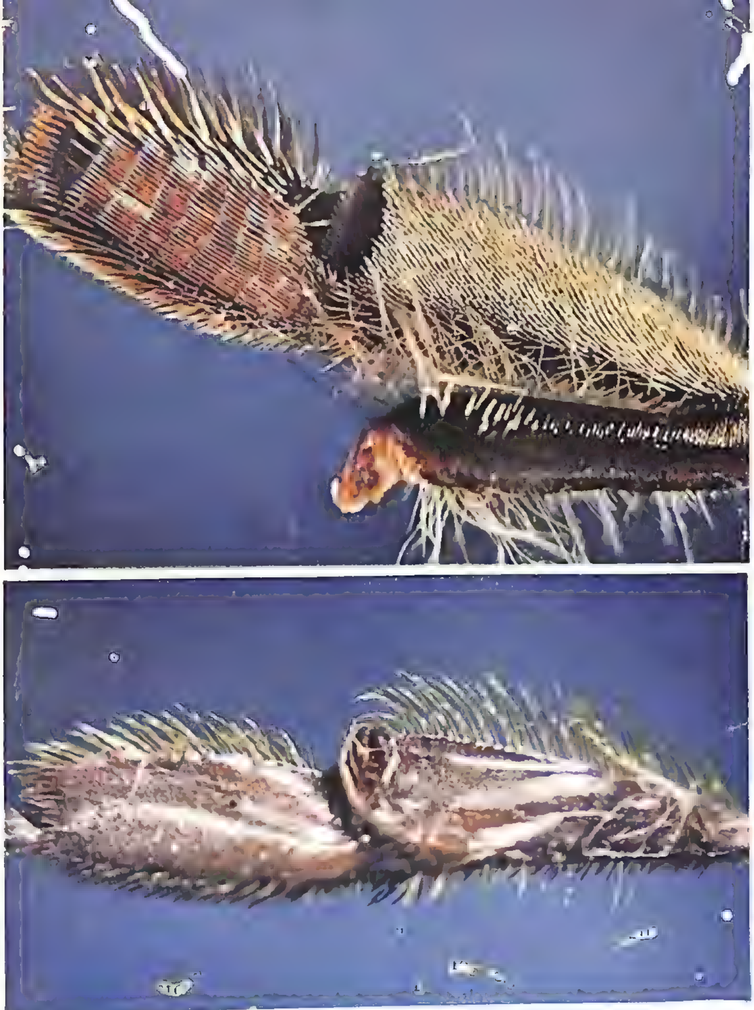
the grasses and are unable to move until the sun reappears. Bees behave similarly as individuals; this can be seen any day in early spring when, tempted by the sunshine to leave the warm hive in order to get rid of excrement, they fly out and if they settle anywhere for a few moments, it may so easily happen that they will lose the power of movement and perish by cold.

Thus, the bee as an individual has a variable temperature, but the bee-colony as a whole has an organisation for constant heat. As already mentioned the 'skin bees' form the limit of this social body. They sit at the edge of the winter cluster closely packed together with their heads turned towards the centre. (Of course from time to time the 'skin bees' change places with others.)

The quantity of food which the maintenance of this high temperature demands, depends partly on the size of the colony and partly on the insulation of the hive and not least on the foresight of the bee-keeper. A strong colony, with its relatively smaller surface, needs correspondingly less food than a weak colony that loses heat more easily. The wintering of bees is part of the bee-keepers' craft. Bees must be well and warmly packed in, but at the same time, they must have enough air so that they do not suffocate. This danger is always present because a great deal of oxygen is needed for such a relatively great burning-up of food in the bees' bodies, and carbon-dioxide and water-vapour are given off in the process. According to general practice, to make up for the honey that is taken away, we give bees a winter store of between 27–34 lb. of sugar in the form of sugar syrup.

We can tell when bees are giving out heat by the gentle vibration of their wings and their vigorous breathing.

Bees do not generate heat only in the winter but also in the summer. They maintain a constant brood-temperature of about 95° F. which approaches the body-temperature of mammals and birds. These warm-blooded vertebrates have attained their independence of outside temperature by their high specialisation. In the case of bees, Nature has arrived at the same goal by welding a multitude of individuals into a higher state of unity.



Above : Brush on the hind leg
Below: Pollen-basket on outer side of hind leg

Queen with workers on newly-founded comb

Honey

Honey is not only the winter food for the bees, it is also the chief source of energy, which they need for movement and for the generation of heat.

It is a highly concentrated sugar solution, which has an aromatic scent and is prepared by bees from the nectar in flowers or from 'honeydew'. This honeydew originates only indirectly from plants; for it is the sugar juice that the greenfly (aphids) secrete when they suck pine-needles or ordinary foliage leaves.

These aphids only make an imperfect use of the plant-juice for they mainly digest the proteins from it and pass out the sugar unchanged as honeydew. In the height of summer the leaves of trees often shine with a sticky coating which trickles down from the upper leaves; well-defined ant tracks over these show that the ants also love this food.

Bees collect honeydew in the summer as soon as the nectar flow is falling off. Honey from this source is mostly dark in colour and if it comes from pine needles it has a harsh flavour.

Honey from flowers on the other hand, is lighter, often golden in colour and in it is combined the smell of wax and of bees and the scent of flowers. The bees make it from nectar, that sweet scented sugary solution which many flowers produce from special glands in order to attract insect visitors. The sugar content of nectar varies not only for each plant but according to the time of day and the state of the weather. The average content is 40 % sugar whereas ripened honey has an average sugar content of 80 %. This high concentration prevents fermentation.

While nectar and 'honeydew' honey produce chiefly cane sugar, flower honey also contains 'invert' sugar—that is a mixture of glucose and fructose both of which are simple sugars—therefore honey, like the commercial glucose that we can buy is easily digestible. These two sugars are responsible for the characteristic way in which honey crystallizes; only the glucose crystallizes out finally, while the fructose surrounds the glucose crystals as a thick paste and keeps them apart.

The transformation of cane sugar into invert sugar is done

during transport to the hive by means of a ferment contained in the honey sac. The house-bees take over the further ripening of the honey. During the warm weather they sit in long rows stretching from the entrance to the inner parts of the hive, and by moving their wings up and down they set up an air current which causes the water to evaporate from the honey.

The honey is not yet in its destined cells but has been divided among several different cells drop by drop so as to increase the evaporating surface. The droplets are later collected and put into the proper cells. (It takes the lifework of 1,000 bees to produce one pound of honey.)

A remarkable observation has been made about this. The freshly gathered honey is divided among several house-bees which manipulate it in the following way: they regurgitate the drops of nectar into their mouths, let it run down between the salivary glands and draw it in again. This process often goes on for twenty minutes without stopping. Of course the foraging bees seldom eat the honey that they gather. The anatomy of the digestive system will show how the bees provide for their own needs by means of their honey sacs.

Real honey can be recognised chiefly because it contains invert sugar and also a slight admixture of pollen grains. The kind of pollen can at the same time reveal the origin of the honey, for microscopic analysis will show from which flower the nectar was taken. Further, from the kind of flower a conclusion may be reached as to the district, even the country or continent, from which the honey came. In this way we can determine whether the honey is home produced or imported.

Honey is not only a source of enjoyment; it is also a natural remedy as it dissolves mucus and has some disinfecting properties. In addition to its high proportion of sugar it contains small quantities of malic, citric and acetic acids and traces of formic acid, all of which increase the stimulating effect of the sugar. The great importance of honey as a country remedy has been recognised for a long time.

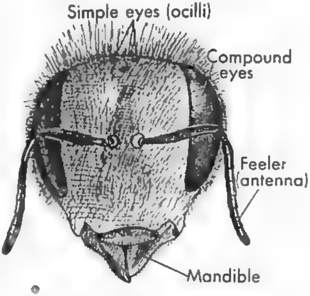
The Structure of the Honey-bee

The whole body of the insect is enclosed in an armoured case which gives it support and provides a place of attachment for the muscles. It consists of a horny substance called chitin. This is a much lighter material than bone but it is equally resistant. Once the chitin is laid down it becomes dead tissue and neither stretches nor grows; therefore the bee-larva, like all insect larvae, makes a new coat several times during development. The chitinous coat of the bee is thickly covered with hair, and to compensate its rigidity it is jointed. Thin places which link the rigid sections together enable the body to be moved; the hardened pieces do not merely fit against one another but grip as well. The beauty and perfection of this jointing when seen under a lens is quite remarkable.

The body of the insect is divided into three main sections, the head, the thorax and the abdomen. Seen from the front the head has a triangular shape and it is made in one piece, like a vertebrate skull. Like every head, it contains the main sense organs, the brain and the mouth. The two large compound eyes are at the sides of the head. They are quite different in structure from the vertebrate eye, though they perform the same function and likewise produce a complete picture. A picture is composed of light and dark or many coloured units and the eye receives it as a complete whole as soon as the single units have been assembled.

The vertebrate eye works like a photographic camera. A narrow aperture with a lens throws a picture on to the retina, where there are many sensory cells, and each of them receives one unit of the picture.

The insect eye, on the other hand, is like a bundle of minute

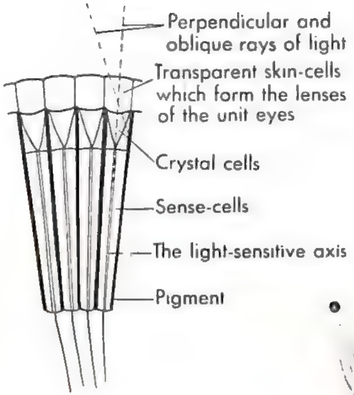


Head of bee from the front

telescopes, each of which is directed on some point in the outside world. It has been estimated that the bee's eye contains about 4,000 such units. They are joined together in a wedge-shape so that their optical axes naturally diverge from one another. The single units are separated by black pigment, and this forms a sheath round the rod that receives the lightray. Owing to this protection, all obliquely-falling rays are eliminated before they reach the sensory cell. By this arrangement, each unit eye sees only the one point which lies on the extension of its optical axis. All these points together yield the whole picture. According to how close together the single eyes are placed, the whole compound eye is enabled to see more or fewer points. The human eye is about one hundred times more efficient than a bee's eye, although this latter is considerably better than that of many other insects. The field of vision of the bee, however, is considerably greater than ours and that is particularly true of the male bees (drones) which can see almost the whole expanse of the sky. Bees also possess three simple eyes (ocelli) which are in the middle of the forehead; they seem to act as auxiliary to the compound eyes by being able to adjust themselves quickly to changes of light, but how they work is not yet fully understood.

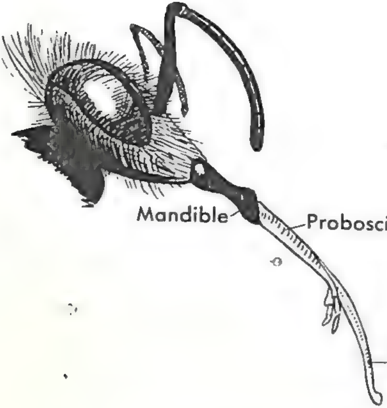
As bees spend a considerable portion of their life in the hive, their feelers (antennae) play an important part. They are covered with thousands of sensory hairs and bear the cells that give the bee its sense of smell, and seen under the microscope these cells appear as thin-walled pores. The jointed structure and flexibility of the feelers make a fine discrimination possible in touch and smell.

The sense of taste is connected with the mouth parts; its special function is to be a guide to the bee in the matter of sweet juices, in which respect the bee is more particular than Man. They will reject a 5 % sugar solution and will only take a 10 % solution when they are hungry or can find nothing better. Man, in comparison, finds a 1 % solution sweet and a 10 % solution very sweet. We can understand that bees will avoid bringing in too weak a solution, because otherwise the work of concentrating it would be too great.



Four units of a compound eye

The position of the major sense organ, already mentioned, is immediately beside the brain. The brain consists of a collection of nerve-cells which stores the impressions of the senses as a whole, brings them into combination with one another, and causes the creature to react. Most insects react quite automatically like the fly that buzzes persistently round the room. Bees do not behave quite so automatically, and this can apparently be explained by the structure of their brain. As well as the special nerve-centres, there is another section of the brain, the 'mushroom-shaped body' which, though it is not in direct communication with any sense-organ, is nevertheless linked up with the other part of the brain by means of nerve-fibres. So we come to the conclusion that bees are enabled to bring at least some small measure of management into the use of their sensations. On the other hand, we must admit that the psychical power of bees is a great riddle and we are a long way from knowing how the different parts of the nervous system are brought into combin-



Side-view of bee's head showing the proboscis extended

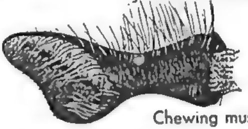
ation. The capabilities of the colony as a whole and its mass-reactions make one wonder if psychic activity is really exclusively confined to the nervous system.

Near the major sense-organ is the mouth; it is at the bottom corner of the triangular head. The mouthparts consist of a pair of mandibles and the proboscis. The proboscis is about ¼ inch long; it is usually folded back under the head but it can be extended when sucking. It is made up of four separate parts, which, in a living bee, can be closed together to make a tube surrounding the tongue. This tongue is ringed and can be moved in any direction. As it is very hairy the drops of nectar cling to it easily; when used in drinking it moves quickly and continually in and out of the proboscis. The bee licks and sips at the same time. At the end of the tongue is a small hairy section shaped like a tiny spoon.

Does the bee use this for sampling or for scraping out the last drops of nectar?

Behind the proboscis the mouth widens somewhat before it becomes the narrow oesophagus. Here we find the muscles which control the sucking mechanism. In the worker bee the large pair of digestive food-glands flow into this channel at the upper end. These glands originate in the head; they only function in the young house-bees.

In front and at the base of the proboscis is a pair of small mandibles which move laterally against each other in chewing; they can also be used as pincers and with these they seize their enemies and push them over the edge of the alighting board. They are also used in carting away dead bees or waste matter and also for manipulating the wax during comb-building. While the outer side of each mandible is simply curved the inner side has a hollow into which the small salivary gland opens. Under the microscope we can see a ring of hairs surrounding the hollow and enclosing in the centre a loose row of thin spines. Are these used in chewing or are they merely of use in seizing objects?



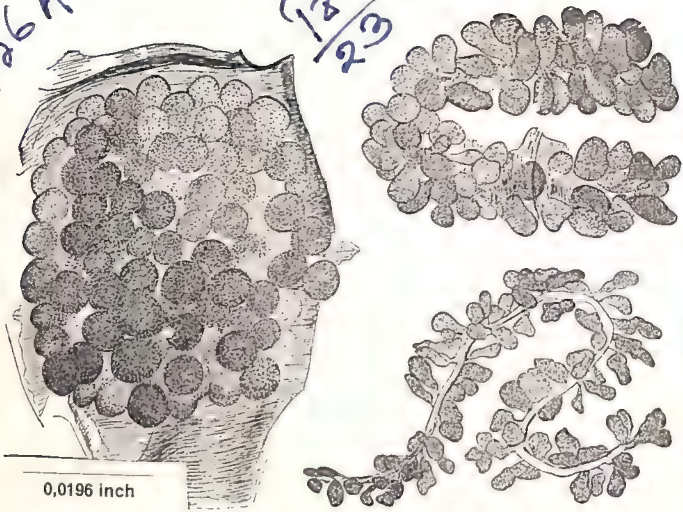
Mandible (inner side)

Another large salivary gland leads to the base of the proboscis but it is partly in the head and partly in the thorax.

The thorax carries the organs of movement: namely two pairs of wings and three pairs of legs. The muscles controlling movement fill the thorax almost completely. It is obvious that the thorax must be very delicately balanced. It has four body-segments which are almost fused together; the upper side and underside can move only slightly against one another and in the respective seams between them the wings are attached.

The wings are operated indirectly, since on the wings themselves there are only small muscles which are responsible for position, for moving the wings forwards and backwards and for turning in flight. The muscles which perform the special work of flight, run obliquely through the thorax and cause it to flatten or expand; they raise and lower all four wings in this indirect

456A 13/23



Food-glands : left, fully developed, right, in process of degeneration. The single saccules open into a common duct

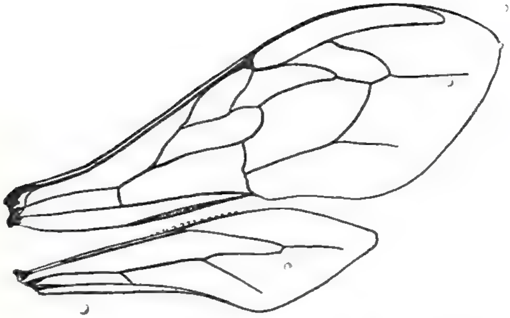
fashion. In flight the front and hind wings are joined together by means of little hooks, about twenty-three in number. These hooks grow along the front margin of the hind wing and engage with the back edge of the front wing which is rolled over downwards. In this way the wing surface is firmer and does not let any air pass between. As soon as a bee settles, the wings disengage and lie over one another along the back. The bee is now thinner and can slip easily through the crowd in the confines of the hive. The hooks of the wings appear to the naked eye as large protruding hairs. The upper wing is slightly hairy.

In general, the wing can best be compared to an aeroplane wing. The veins which stretch and support the double wing

Left: cross-section through the thorax, showing indirectly-acting wing muscles and the directly-acting muscles which control the up and down movement of the thorax. Right: the same in longitudinal section

correspond to the spars; they strengthen particularly the front edge of the wing which cuts the air when flying and the back edge runs out flat; so that the cross-section resembles that of a bird's wing, where the hand-bones strengthen the front edge and the wing feathers run out behind. Such a wing-profile avoids the formation of eddies. It has already been established, first from the humming note of a flying bee and also by photographs and films, that a bee makes 200 wing-beats a second. In each single beat the *wing-tip* describes a figure-of-eight, because as the wing beats forward and backward, the slope of the cross-section of the wing is less to the horizontal in the forward stroke than in the backward stroke, while in level flight.

Like the muscles controlling the wings, the leg muscles also are attached in the thorax and from there long tendons pass into the joints of the legs, which they control. With their seven-jointed structure, the legs are capable of varied movement: they are not only useful for walking but also for cleaning the body. A bee uses its front legs for combing and cleaning the head, especially the eyes and feelers; the middle legs for brushing its sides, and the hind legs for cleaning the underside of the body. The only piece of the body that the legs cannot reach is the middle of the back, so this has to be done by one of the other bees. They communicate their wish to be brushed. In the course of careful observation, it has been found that bees mostly have a clean-up



Fore and hind wing of bee, showing the fold on the hinder edge of the fore wing and the hooks of the front edge of the hind wing

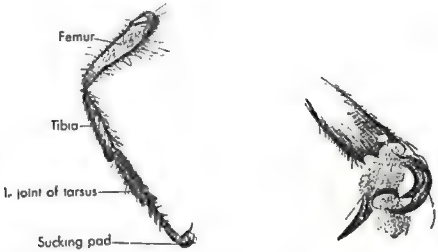
between two foraging flights. It happens like this: first the bee brushes itself as much as possible and then suddenly begins to shiver violently. This draws the attention of another bee which hurries along to help and cleans the first one's back with its mandibles. During this operation the forager stands quite motionless and passive.

Cross-section through the in-rolled hinder edge of the fore wing showing the hook engaged

A lens will reveal the presence of special cleaning appliances. All three pairs of legs have a kind of brush made of thick hairs

on their inner sides. The front legs have, in addition, a wonderful little comb curved into an arc, its diameter corresponding exactly with that of the antenna. It will be found in the curved hollow at the top end of the first joint of the foot (tarsus). When a bee wants to clean the antenna, it draws it down into this curve, and slightly closes the upper leg joint; from this joint a fold of skin hang downwards and presses against the antenna, which is then pulled through. In this way it is throughly combed out and freed from dust or pollen.

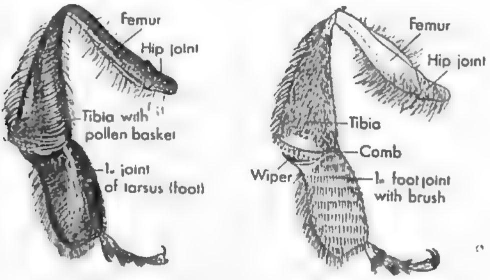
The brushes on the hind legs are not only used for cleaning but are of special importance in pollen-collecting. Bees collect pollen from flowers with their hind legs and carry it on the outer sur-



Left : middle leg of bee. Right : sucking pad greatly magnified

face. The lumps of pollen are held in the 'pollen-baskets'. This basket is on the tibia and is a bare cavity surrounded by long, curved hairs. In the centre of this bare space a single hair stands upright, and this provides a pole round which the pollen is heaped up. How does the bee get it into the basket? That used to be their own secret; it is difficult to make a close observation of the process for the reason that the 'basket' is built up during flight. The way this equipment works was first discovered from

the humble-bees which are related to the honey-bee. The secret was revealed by them when they were flying quite slowly in the cool of the early morning, and the passage of the pollen-grains from the anther of the flowers into the pollen-basket was observed. Later observation confirmed that the process was the same in honey-bees; we now know that, as they crawl busily over the stamens of the flowers sometimes biting off pieces of them, the bees first moisten the pollen with honey out of their mouths to make it sticky. Then with the big brushes on the inner side of the hind leg, they brush off the pollen from the stamens and from the underside of their own body. Between the first joint of the tarsus (the joint that carries the brush) and the tibia (which carries the basket) is a coarse comb. With this the

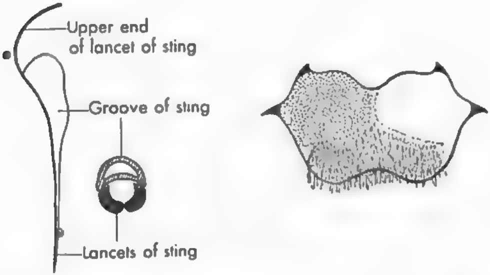


Left : hind leg with pollen basket (outer side). Right : hind leg with brush (inner side)

bee combs out the pollen brush by crossing its legs, so that the comb of the right leg is used on the left brush and the comb of the left leg on the right brush. In this way the pollen reaches the lower edge of the basket, and a little wiper, in the form of a curved spine at the top of the brush, pushes it up into the mould.

As the bee goes from flower to flower, rubbing his hind legs together during each flight, more and more pollen is pushed into the basket. When the basket is full, the forager flies back to the hive, seeks out a pollen cell and pushes off its load. The weight of a single basket is about 12–29 milligrams and the two together may be as much as half the weight of the bee.

Although the three pairs of legs differ considerably in each having their own modifications which we have just described, they are all similar with respect to the terminal joint of the foot. (The feet of cockchafers end in claws, those of flies in a sucking appendage, but the feet of bees have both.) Between the two pairs of claws which are designed to get a grip on the yielding comb or on any rough surface, there is a cushion-like ball, a kind of sucking-pad which holds on a smooth surface. When the claws slip on a smooth and shiny flower-petal, they are at once flexed back so that their points lie upwards, and at the same time the horse-shoe-shaped sucking-pad is exposed. The folds of skin, which cover it when it is retracted, now spring open, a sticky juice is exuded and the foot holds firmly on the smooth surface.



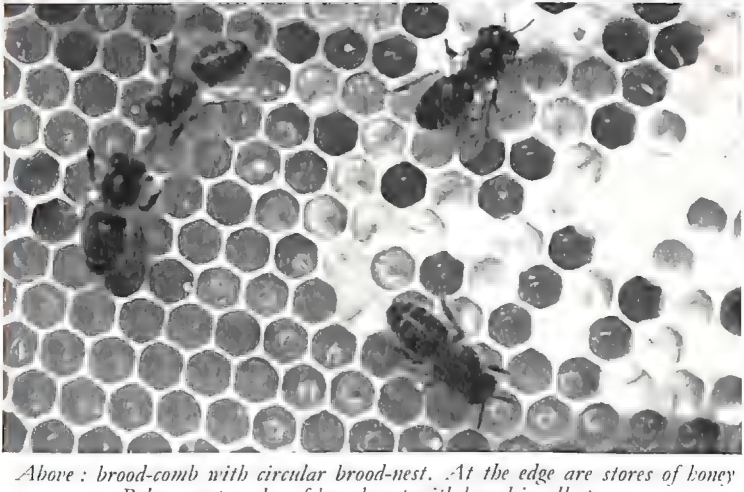
Left : Bee-sting from the side and also in cross-section
Right : single scale of abdomen. The upper piece which is covered by the following scale is porous

The sting is also a very complicated affair. It is at the end of the abdomen. In many insects it has developed as an ovipositor, but the sting of the worker-bee, like that of the queen, is solely a weapon. Under the microscope it is seen to consist of three parts which together make a tube pointed at its end. The three parts are a grooved structure with two lancets running along in the groove and closing it below. It is along this groove that the poison flows into the wound from a large poison sac. The two lancet have barbed tips and slide in and out of the groove as if on rails. In operation the sting does not *push* into the victim's skin but *saws* its way in. What happens if a bee has stung a human or other mammal is this: because the skin of mammals is elastic, it is drawn together round the little barbs of the sting and holds it fast. The bee, striving to get free, tears the sting out of its body and dies from this great wound. But if a bee stings another insect enemy, an open hole is made in the insect's hard coat through which the sting can easily be withdrawn. The queen's sting is rather stronger and is slightly curved; she only uses it against her rivals.

In contrast to the head and thorax, the abdomen of the bee is composed of more flexible segments, which enables it to bend, stretch and expand. This flexibility is necessary for breathing and for stinging. Thus the abdomen can expand when the bee takes up honey or water and in the case of the queen to accommodate her swollen ovaries.

On the underside of four of the six segments are wax glands; they consist of several thousand cylindrical cells. There is a pair of these on each segment and they are covered over by the segment behind; at these places the scaly integument is perforated with fine pores so that the wax, which is at first fluid, is exuded through them and only solidifies between the two segments in the 'wax-pocket'. Thus, bees can produce eight wax-tablets at a time. It takes 1,250 tablets to make 1 gram of wax. The bee pulls the wax-tablets out of the pocket with the hind-leg and guides them over the middle legs to the mandibles, which knead it into shape and deposit it in its proper place on the comb.

For the production of wax, which is a fat-like substance, bees



Above : brood-comb with circular brood-nest. At the edge are stores of honey
Below : outer edge of brood-nest with brood in all stages

"*Stocking*" *on the outer side of the hind leg*

Longitudinal section through abdomen showing position of wax glands

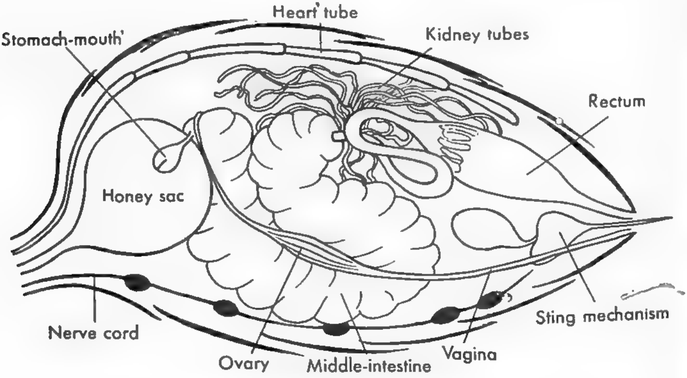
need carbo-hydrates, which are carried by the blood from the intestine. Bees can only produce wax when they are sufficiently nourished with honey or sugar solution.

In bees, as in other animals, the blood is used as the means of transport of materials in the body, but in insects there is a difference in the way that a circulation is maintained. Insects have an open circulation, that is, the blood does not flow only in blood-vessels but washes freely round the organs. In bees a single vein just under the back runs from the end of the abdomen to the head. Because the vein is especially broad in the region of the abdomen and pulsates there this part is called the 'heart'. The heart consists of five chambers folded in one behind another; through openings between the folds, which act as valves, the blood is sucked out of the abdomen and pumped up towards the head. Here, then, a continuing supply of blood has its origin and it flows in open channels through the thorax and so back into the abdomen. The stream is directed by two thin muscular membranes which are spread out above and below the intestine, thus dividing the abdomen into three horizontal compartments.

An open circulation is possible in insects because the blood has nothing to do with the transport of oxygen, for this is supplied directly by the breathing system. (For this reason the blood is not

red, as it is in most other animals, but is colourless; for it is the red colouring matter alone that has the property of taking up oxygen for conveyance to other parts of the body.)

The breathing apparatus of insects consists of a series of tubes (trachae) with open breathing pores (stigmata). The pores occur on either side of the body, one pair to each segment; there are three pairs on the thorax and seven pairs in the abdomen. These stigmata are protected from the penetration of dust and damp by being enlarged at the entrance where a growth of fine hairs acts as a sieve. From here the trachae branch inward; they are lined with a thin layer of chitin, which indicates that during the development of the young bee they were produced by the inward growth of the outside surface. They are true air-passages and, like our own windpipes and bronchial tubes, are kept open by having strong bands of thickening so that the air can pass in and out, as the abdomen moves, with very little resistance. Inside the body they branch into finer and finer tubes, become more and



Abdomen showing intestine in longitudinal section

more thin-walled and form a net-work surrounding the organs as silvery air-capillaries. In combination with the tracheae there are large air sacs, which are the means of making the structure lighter for its size and so make flying easier.

The abdomen contains the intestine, with its excretory system, and the sexual organs. The honey-sac into which the oesophagus opens is usually considered as part of the intestine. When the honey-sac is full it weighs about 75 milligrams. In this condition it crowds the rest of the intestine close together and makes the abdomen expand. As we have already learnt this honey-sac acts as a reservoir. It has been called the 'social stomach', because bees do not keep the contents for themselves alone, but divide the nourishment equally among their companions in the hive. The individual nourishment of a bee is safeguarded by having a kind of small suction-pump connecting the honey-sac with the intestine. Through the four slits of this mechanism, known as the 'stomach mouth', honey or pollen grains can be taken out of the honey-sac and passed into the digesting portion of the intestine. It works like a valve. for the contents of the stomach cannot pass back into the honey-sac. The middle intestine is lined with cells which secrete the digestive-juices; it lies coiled in a loop in the abdomen where it takes up a large space. The lower end narrows and becomes the rectum which collects the excrement, and also the liquid excretion, absorbed through the kidney tubes. The two waste products are voided at the same time.

In speaking of the sexual organs we must now go on to say that in a bee-colony there are three kinds of bees which agree in their general structure but differ in several details.

Drones, Queens and Workers

The bulk of a bee-colony is made up of 40,000 to 60,000 workers; there is only one queen, and from a few hundred to 2,000 drones.

The drones are the male bees, they are three-fifths of an inch to two-thirds of an inch long, and proportionately broad. They cannot sting nor can they feed themselves: they have to be fed by the workers. They do not have the special modifications of the workers such as the pollen-collecting apparatus; the wax-glands are altogether absent in them. They have no other function except that of fertilising the queen. As fertilisation occurs in flight, their large eyes and feelers are of great importance in locating the queen, as also are their long wings with powerful muscles for overtaking rivals in the chase. Drones are sexually mature on the twelfth day from emergence.

Queens and workers both have ovaries and are therefore female. The ovaries of the worker-bee are mostly very small, only about one-fifth of a millimetre wide and four millimetres long. Being so small, they were only identified shortly before 1800 by François Huber, of Geneva and his assistant.

The sex-organ of the worker consists of a few egg-tubes (ovarioles) and can in certain circumstances produce eggs capable of development, particuarly if the hive loses its queen. The remarkable thing about such workers' eggs is that they only produce drones, a fact that was not explained for a long time. Old or diseased queens sometimes lay only drone-eggs and are then called 'drone-layers'. It transpired finally, that drones were always produced if the eggs were not fertilised.

The development of unfertilised eggs is a contradiction of the law that says life cannot be produced except from fertilised eggs.

The present exception to the rule holds good for the *sex* of the young bee, in that out of an unfertilised egg, a drone always comes, but out of a fertilised one a worker or a queen develops. Because the worker's vagina is much too narrow, she is debarred from mating and so by her egg-laying she is unable to save a queenless colony.

If a queen is mated with a drone of a different breed, the worker-bees resemble both parents, the drones only their mother. The opportune chance of a race-difference between the two sexes of a colony has led to the discovery that drones have no father. Anyone who is interested in genealogy can see for themselves from the table on page 34 that a drone has only *one* grandfather, *one* grandmother; *two* great-grandmothers and *one* great-grandfather. It also sets out that workers and queens in contrast to other creatures show a diminution in the number of ancestors. They have only *one* grandfather, *two* great-grandfathers and *three* great-grandmothers.

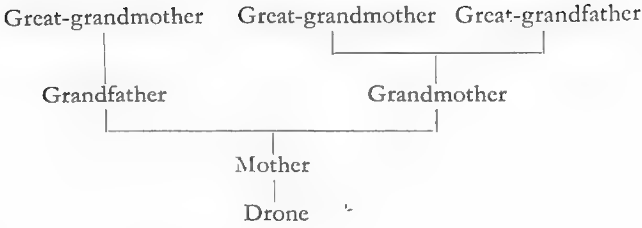
The fertilised eggs produce females, either workers or queens; which of the two it is to be, is decided within the first three days of larval life under the direction of the nurse-bees. If a colony suddenly loses its queen, whether by disease or by some other mischance, a new queen can be raised as long as there are eggs or one- or two-day old larvae present in the hive. If on the other hand the colony has no young brood, the bee-keeper, if he has noticed the loss of the queen, puts in a brood-frame containing eggs from another hive. Then the leaderless colony will not neglect to rear a new queen.

The secret of this transformation of the larvae by the workers was recently solved after ten years patient research. It now seems to be established that it is brought about by traces of hormones and perhaps some vitamins which the nurse-bees mix with the ordinary nourishment. While a queen can be reared from any fertile egg and also from one- or two-day old larvae, this is no longer possible with three-day old larvae.

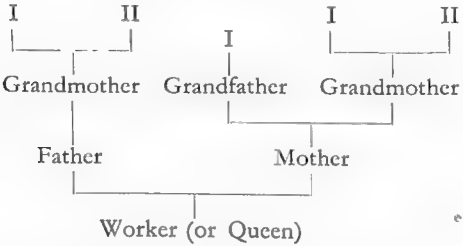
The larvae destined to be workers are given 'worker-bread' in the first three days which determines their development as such. In the second three larval days they are given 'bee-bread' that is a mixture of honey and pollen to which a new active material has been added. The queen larva is given 'royal-bread' throughout its larval life and receives it in such generous measure that a considerable amount is left over in the cell after pupation.

Although the worker bees are smaller than the queen (three-fifths of an inch long) and their ovaries show divided cell-

Family-tree of drone



Family-tree of female bee

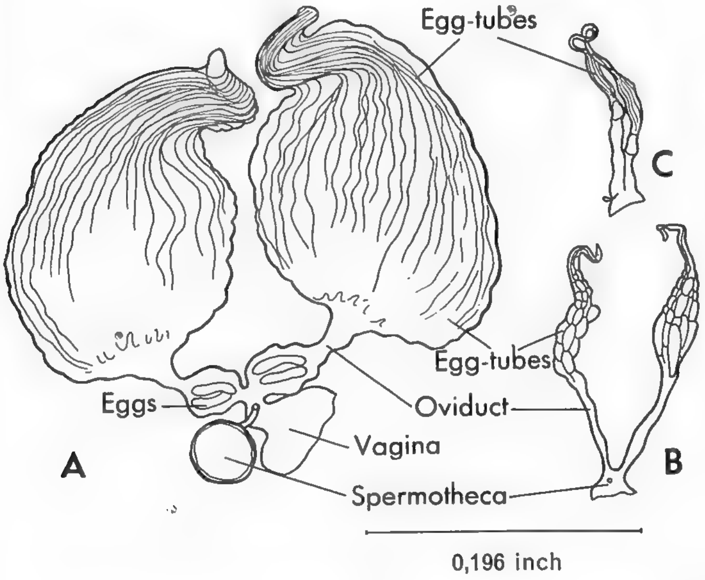


I = Great-grandmother, II = Great-grandfather

masses, we can really only describe them as stunted females. There is, however a definite sharing of the maternal duties by the two different and specialised females. While the queen is solely dedicated to egg-laying, the workers take over all the other duties of a mother, in building the nest, keeping the hive clean, fetching in food and looking after the young bees.

The queen lacks the special organs and instincts which the workers possess. Her proboscis is shorter than that of the worker and cannot reach as far into the honey cells. She is mostly fed by the nurse-bees. While the queen is walking over the comb they cluster round her and give her food there whenever she demands it by stretching out her tongue.

The queen is four-fifths of an inch long and she can be recognised by her long abdomen. Her abdomen is filled with eggs.



Ovaries under the same magnification : A queen-bee, B a laying worker, C worker from a normal colony

Each of the two ovaries is made up of 140–160 egg-tubes (ovarioles). The upper ends of these contain nuclear material that continually produces egg-cells and nurse-cells alternately one below the other. In their journey downwards the egg-cells grow into well nourished eggs by absorbing the nurse-cells and finally pass into the vagina. Here the egg can be fertilised because the vagina is connected with the spermatheca by the spermathecal duct. This passage is constricted at its upper end to form a suction-pump which can either break the connection between the spermathecoa and the vagina or, on the other hand, force spermatozoa down into the vagina; and this is the way in which the fertilisation of the eggs is regulated. What determines the opening or closing of this spermathecal pump, we do not know. We can only state definitely that there are two sizes of cells in the comb and that as a rule the queen lays unfertilised eggs in those with the larger diameter and fertilised ones in those with the smaller diameter.

The ovaries of a queen are so efficient that in her best laying time she can produce an egg about every forty seconds, that is a thousand to two thousand in a day. Her output surpasses that of most other known animals.

The efficiency of the organisation of the queen-bee is possible because she concentrates entirely on egg production and in busy times does not have to digest her own food. During this time she is supplied with glandular juices, which contain the necessary elements in the right proportions and do not need digestion. By this pre-digestion of foods on the part of the nurse bees for their queen, egg production is increased. Comparing the ovaries of a queen-bee with that of a queen-wasp, for instance, the queen-bee appears to be a kind of super-female, for the ovary of the ordinary queen-wasp is very much smaller and on the whole is more like that of a laying worker-bee.

Since the majority of eggs produce workers, the egg-production by the queen leads directly to an increase of the colony. All the worker bees of a colony are sisters. When they have fulfilled their time they die leaving no descendants.

In order that a new generation may arise and reproduce a colony in the future, new queens have to be provided. This leads to a division of the colony, for several queens in a hive cannot tolerate one another. The increase of the colony takes place usually in May. At this time the bees prepare a different type of cell, the 'queen cell', in which the queen larvae are to be reared. The queen cells when finished are so long, that they cannot be fitted into the pattern with the other cells in the comb, so they are mostly found at the edge of the comb where they hang down like little pegs about one inch in length. The bees usually bring up several queens at the same time though only one or two, possibly three, of these will be used.

In order to avoid being taken by surprise, it will be to the advantage of the bee-keeper to look over his colonies at this time, so as to have an idea where the queens are being reared.

It takes sixteen days for the development of the queen from the egg to her emergence as the mature insect. When the time

Two queen-cells built on the edge of a frame

comes, she escapes from her prison by cutting neatly round the lid with her mandibles. By this time, perhaps even a week before her mother, the former queen, will have left the hive. One fine day she will have flown out with almost exactly half the bees in order to found a new colony elsewhere.

At the time of swarming, the bees, young and old, first crowd over the honeycomb so as to fill their honey bladders with a supply of food; then they leave the hive in wild haste, pouring out of the entrance like a stream of water and circle round in the air in a real tumult until the queen settles somewhere. There the swarm collects. This swarming of the bees is a rousing event, for such a swarm must not be lost. The first or 'prime' swarm is particularly valuable because it contains a good laying queen. She will go on laying at once and will bring the young colony quickly up to strength.

Swarming bees are not likely to sting and the spectator is not in any danger. As the queen in this first swarm is fairly heavy in the body with eggs, she will not fly away too far but will settle down perhaps on the branch of a tree. The bees hang on to her and each other and make a cluster, which gradually grows in length downwards. This is the swarm. Ultimately all the bees are clustered in a bunch except for a small number that still hover around outside. If the bee-keeper does not take this swarm —perhaps he has not noticed it—the bees stay there for a whole day or less according to circumstances and then fly off to a new home which the scouting bees have sought out for them. This may be a hole in a tree or an empty hive.

As Lindauer has recently discovered, many scouts go out on this mission. Having found a suitable shelter for the new colony, these bees tell the swarm about it by definite and well-known signs; for they make use of the same sign-language which is used in the hive to call attention to sources of food-supply. (We shall be speaking of this sign language in the last chapter.) It consists in 'dancing' to a pattern, and in this case, the more suitable the shelter seems to them, the more intensively do the bees dance. It is as if they carried some ideal picture of a home in their minds and were now comparing the newly-found hole or

hive with it. The bees that 'dance' most violently draw more and more scouts to their side; these follow the signs, take a look at the shelter in question and then announce their agreement to the swarm by joining heartily in the dance with the others. If a hundred or more bees elect to go to a given place, then the swarm breaks up and follows the pioneers in a dense cloud. Accordingly to Lindauer, the scouts, keeping between the head of the swarm and the main body, buzz noisily back and forth.

It is quite astonishing that a swarm can send out scouts in this way to find a new home, also that these scouts can direct first a few, and then a whole colony to the chosen place. Such a migrating colony flies at top speed, and we may perhaps have an opportunity to see this in a favourable year for swarms. The swarm, like a little cloud, suddenly sweeps up over the trees and the next moment it has already disappeared on the other side. It can happen, that particularly small swarms which are not taken may simply remain hanging and then begin to build there in the tree, until rain or storm washes away the unprotected work and the bees perish.

Usually the bee-keeper takes his swarm the same day; he puts a box under the swarm and then with a short sharp stroke on the branch he hits it off into the box. If however, the swarm is in an awkward position, for example among small twigs, he has to brush the bees very carefully into the box in case the queen should fly off again. Once the queen is in the box those bees that may have been scared away by this procedure come back again and reassemble there. The box is put into a cool place for two or three days, that is, during the time that there is still a danger of the bees flying off. When the wish to fly is finally quenched the swarm can be lodged, that is they are brought into the hive kept ready for them.

In order to keep his colony the bee-keeper gives them some comb foundation for building. Usually the bees set to work at once and the queen recommences her interrupted task of egg-laying.

In the old hive the young queen is now emerging. If the old colony was very large or perhaps for some other cause, it may

happen that this new queen may also fly out with half the remaining bees. It is obvious that the secondary swarm is not so valuable as the prime swarm. It is indeed only half the weight of the first and has a queen that is not yet fertilised. On the other hand if she stays in the hive in which she was hatched, she will now kill the other unhatched queens. At this time we hear her 'singing' that is she makes a sound rather louder and different from the ordinary tone of the hive. It sounds like a 'tu–tu–tu'. The sound is made by the vibration of the chitinous plates at the base of the wings. To this 'tu–tu–tu' the hatching queens in their closed cells answer with a 'quak' which is a much duller sound. The new queen goes to these cells, bites them open, and stings her rivals to death. However, if the bee colony has the desire to swarm again they will protect the imprisoned queens and the singing will no longer be heard.

The Nuptial Flight

Whether the young queen has swarmed out or stayed with the mother hive, she must first be fertilised before she can begin on her activity of egg-laying: hence she must set out on her nuptial flight. On the first fine day after she has left her cell she flies out from the hive, alone. The bee-keeper is able to estimate the time at which this important flight will be made. If he is right in his calculation he will be able to watch the entrance hole. Perhaps he will actually see the queen appear and fly away from the alighting-board. The queen first flies around in short circles to get her bearings to the entrance of the hive so as to impress the place on her consciousness and be able to find her way home. Then she flies away and the bee-keeper anxiously awaits her return; she may lose her way and be killed in a strange hive, she may be eaten on the way by a bird or a dragonfly or she may be unable to find her way home and fall to the ground somewhere in the grass.

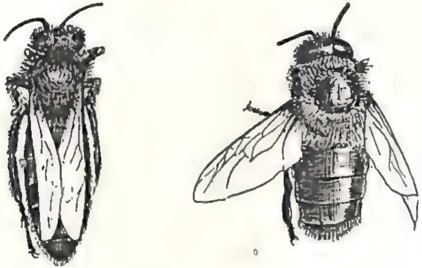
Now during swarming time there are drones at hand in all the hives and they come tumbling out into the air in hundreds; for

with their well-developed senses of sight and smell, the drones are at once aware of the presence of the queen and join in the hunt after her.

Once a queen is seen at the forefront of such a pack of drones the mariage-race cannot be followed any further or be described with real accuracy. We can only conclude from the structure of the male sex organs that in the act of union a portion of this apparatus is turned inside out and is shot into the vagina of the queen together with the mass of spermatozoa. The drone dies in the process. The queen returns to the hive and the watchful bee-keeper knows that she has been fertilized when he sees the 'marriage signs'—tiny white threads hanging out of the end of her abdomen. These white threads probably come from the plug of mucus material from the drone and it now closes the genital aperture of the queen from the outside.

The millions of spermatozoa are now in the vagina and oviduct of the queen; they move gradually into the sac designed for their storage which is called the 'spermatheca'. Here they are further nourished by secretions from a gland.

After some hours the worker bees remove the marriage signs from the body of the queen. The store of spermatozoa lasts for three or four years for the fertilization of the eggs, which during all that time are being matured in the ovaries, ready to pass



Left : queen-bee. Right : drone

through the seminal deposit at the mouth of the spermatheca. A queen can be impregnated only once in her lifetime.

As with other domesticated animals man has tried to control the breeding of bees, but with them this is not so simple. Various countries have set up breeding stations in isolated places such as a forest glade, which is so far from other bee colonies that one can guarantee that foreign drones will not come rushing out over the station. The breeding station itself keeps pure-strain colonies of any kind of bee that it may wish to reproduce. Bee-keepers can thus ensure the fertilization of their own queens by bringing them here together with a few hundred bees in special breeding hives, and setting up these miniature colonies on the meadow. In this way breeding can be controlled. Even surer is the method of artificial insemination which is done under a microscope; this is fairly widely practised in America.

Once the mating season is over, that is, in July or August, the worker-bees gradually get rid of the now superfluous drones. These are no longer fed and as they cannot feed themselves they become more and more exhausted and are thrown out of the hive by the workers. This is known as the 'slaughter of the drones'.

Marriage has stimulated the development of the eggs in the body of the queen. The ovaries swell and consequently the abdomen increases in size which indicates that egg-laying begins two to four days after the nuptial flight. The rate of egg-laying depends on the time of year as much as on the size of the colony and the available food supply. It is at its greatest in early spring; then the colony is growing. In the course of the summer it falls off, and then in August and September, it starts afresh. It is now that the over-wintering bees are produced.

This egg-laying is quite a ceremony. The queen walks majestically from cell to cell, puts her head down to inspect then turns round, lowers her abdomen into the cell and lays the egg. Now she goes to the next cell and repeats the process. The eggs are laid in a definite succession; the queen begins in the centre of the comb and goes round in a spiral to the outside. Consequently the brood-nest grows from within outwards, making a circle at

first on the innermost comb. Then the queen begins on the adjacent combs. The shape of the whole brood-nest is therefore spherical, the most favourable shape for conserving heat. Bees incubate the brood, as we have already mentioned, at a temperature round about 95° F.

Since the queen lays from within outwards, it follows that the oldest brood will be in the middle. When the innermost bees have hatched out, the queen again visits the centre and a new generation, replacing the first, grows again from the centre to the edge. Scattered over the brood comb are stores of pollen and honey as well, so that the feeding nurse-bees and the newly hatched young ones have food close by them.

The Development of the Bee

Owing to the even brood-temperature, the development of the bee is rapid and as in warm-blooded animals takes a definite time; it goes through successive well-marked stages and the whole process takes twenty-one days.

At first the egg stands upright in the cell. It is elongate and about the size of a caraway seed. Towards the end of the third day, it bends over and the larva hatches out. It is maggot-like, about one-sixth of an inch long and has no proper head and no feet. The intestine at this stage, is a relatively large sac, for the business of eating takes first place in the life of a larva. It absorbs food even while hatching and receives so much secretion from the food-glands of the nurse-bees that at first it fairly swims in it. As the intestine does not go right through the body, the excrement is kept inside and does not soil the food; it is only cleared out at the beginning of pupation.

All this time, the larva is visited by the nurse-bees, sometimes only for a short inspection or when being fed. During its five and a half active days the larva receives more than ten thousand visits from the nurses. The good work goes on. The larva grows quickly, casts its skin once every twenty-four hours, and as it gets

bigger, lays itself down at the bottom of the cell, first in a half-moon shape and then as a ring.

After the first three days, there is a change of food. The larva is now kept on short rations and receives the ordinary bee-food, that is a mixture of honey and pollen to which an active ferment is added. After this short period of five and a half days the larva completely fills the cell. It is now 500 times as heavy as when it first came out of the egg, and its inside is full of fat globules.

At the end of the sixth day (that is nine days from the time the egg was laid), the larva becomes a pupa. It has spun a fine web (the 'pupal shirt') as if it had to spin a whole cocoon. Then, usually at the end of the eighth day, the other bees close over the top of the cell by means of a porous wax lid and all later development goes on under cover. To see what happens, we have to open the cells.

On the tenth day the larva stretches itself out and lies at full length in the cell. It now casts its skin for the fifth time. Gradually the long 'grub' begins to show the three parts of the adult body by folding; further folds make the separate segments of the body. The legs and the feelers grow out and only the wings are still confined in the little 'wing-pockets'.

Finally the pupa bursts its pupal coat and there is the new bee, perfect in all details.

The development of its interior has kept pace with its exterior. A portion of the larval organs have been dissolved and built up anew. This is made possible through its having the stored fat globules.

A few days before emergence, the skin begins to darken, at first the eyes, which become quite black, then the whole body turns brown. When, on the twenty-first day from the laying of the egg, the adult bee emerges from its cell, it is still relatively light in colour, the chitin is still soft and the body is thickly covered with hairs. By these signs we recognise the young bee. Later on, the outer coat becomes harder, less hairy, darker and more shiny.

Nurse-bee on brood-comb with some cells sealed over

A forager at work

The House-bees

The young bee frees herself from her cell; she does not cut the lid as neatly as the queen, but rather crumbles it with her mandibles. Even before she is fully out, she stretches out her proboscis to be fed. She is hungry, for her inside is quite empty. Eating is again important at the beginning of this new stage of life, for within a week the newly emerged bees will become nurses themselves, and will be able to secrete the 'bee-milk' from the special food-glands, which from now on must be encouraged to develop. This glandular juice is rich in fat and albumen, so the main food of young bees is the protein-rich pollen. Before long they find the stores of pollen in the upper part of the brood-comb and feed themselves.

Then they set to work to clean out cells. They chew off the bits of cell-lids, take out the waste matter, and varnish over with their spittle the remains of the old pupal skins. In fact bees spend a considerable part of their life in cleaning work. They are hardly out of their cells and dry, before they begin cleaning and brushing themselves, and then turn to tidy out the cells they have just left. In this way as every bee works over several cells, each one being cleaned several times over.

About the third day after emergence the bees take charge of the larvae of three or more days old and feed them with the same food they eat themselves, that is, pollen and honey. The field of work of each new member of the colony increases daily. At first the bees stay on the comb in which they were born, then they go on to all the other combs in turn until, at last, they have fulfilled their duties throughout the hive. Last of all they leave the hive to take their part in foraging.

How is it that each bee knows her appointed task in this crowd of ten thousand others? The number grows daily until there are about 2,000 new bees; in the whole concern good order reigns and the different activities are carried on without any friction. It never happens, for instance, that all the bees flock out into the sunshine, leaving the young brood to starve.

Everything is regulated and worked out in detail as if some

controlling element were at work. Of course it is difficult for us to imagine an organising power which is not allied to consciousness or personality. That it really can exist and that Man's brain is not the only seat of reason seems borne out by this case of the bees. They are creatures of instinct and not mere machines.

Instinct is the name we give to an inborn ability which does not need to be learnt, and it mostly follows the same general pattern. Bees are exceptional in this, for in their case, they prove that instinct is adaptable. Like any other large organisation, the bee-colony is constructed on the principle of division of labour.

Special 'observation hives' are made now-a-days, in which the frames, instead of being closely parallel as in the ordinary hive, are spread out end to end so that the whole surface can be seen at the same time. If, in one of these hives, we daily mark the newly-emerged bees with different-coloured spots, so that finally the greater part of the colony is carrying its birth-date on its back, then we can easily see each age-group at its appointed task. We see that bees divide the work among themselves so that for each step in age there is a corresponding task, and each bee goes right through the detailed programme once.

The bee-colony represents the most complete social state that can be imagined. As every member of the community is allowed to enter each profession, there is no need for any one to be jealous of another. It is a pity that such a frequent change of work is possible only among these creatures of instinct, which need neither education nor pratice and at any moment have the necessary equipment and knowledge to hand.

The young bee has been busy cleaning cells for the first three days of her life, and next, feeding the older grubs up to her sixth day; now she takes over the feeding of the young ones. She works as a nurse from the sixth to about the twelfth day because this is the time when her special food-glands are secreting copiously. Bees of this age also feed the queen at the time when egg-production is at its height. After the period of nursing, the bees move about in the hive and may even begin to take their first flights. These flights are purely for orientation; they fly only a little way from the hive and always keep their eyes on the entrance

hole. This is the way these bees learn the situation of their home. First, they learn where the entrance is, then the shape of the hive and its general surroundings. On a fine day there is a regular commotion—the 'play flights'—which the bee-keeper is pleased to see for he can then look foreward to having a large army of foragers. The foragers themselves are much less easily noticed for they fly off the alighting-board at once and come straight back again.

The life of a bee seems, in all, to consist of three parts. We have already described the development of the larva; also the scheme of work of the full-grown bee. Now we come to the foraging activity which normally begins on the twenty-first day after the bee has come out of the cell. From the twelfth to the eighteenth day, these house-bees again take part in cleaning operations. They are now able to carry heavier loads of dirt out of the hive and drop them some distance away. They also run to meet the foragers down by the entrance to take their load of nectar; this they divide among themselves to work upon with their mouthparts and finally to deposit the product in the honey-cells. In the same way they look after the pollen-harvest. The foragers, of course, bring the pollen themselves into the appropriate storage-cells; the 'baskets' cannot be given to another bee. The foragers push off the contents of the pollen-baskets and leave them for the house-bees to crush and bite up the pollen, finally to pack it tightly into the cell. By this close packing the largest possible amount of pollen is packed into the smallest possible space. When a cell is full it is covered over with some ripened honey to make it keep. None will deny that the bee is a professional in the art of preserving. Man may imagine that he discovered the way to preserve food-stuffs, but as we see, the bees thought of it first.

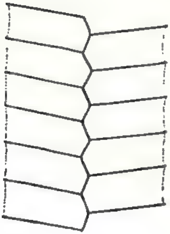
Another activity of bees of this age (twelve–eighteen days) is covering the honey stores and also the brood when they are ready to pupate. They take the wax mostly from the cell walls; we can tell this because the lids are the same colour as the comb they cover. Comb-building is also carried on since at this stage the wax glands begin to function.

The twelve–eighteen day old bees also take on guard-duty.

Bees have many enemies such as the wax-moth, the larvae of which feed on wax; and all the many honey thieves. These may be hornets or wasps, or more often, bees from another colony. Such bees, attracted by the smell of honey try to get some for themselves in this easy way. If a robber-bee once succeeds in entering a foreign hive and gets away again, she will return again and again bringing others with her, in ever greater numbers. The bees dodge around fighting over the alighting-board and may even be seen hanging in small clusters at the edge. Then the 'guards' biting and stinging, try to push the enemy over the edge of the alighting-board and drive them away.

The bee-keeper can help the oppressed colony by narrowing the entrance hole so much that only one bee can enter or leave at a time. This makes defence easier. Otherwise it may happen that a colony may be completely plundered and the original bees taken away by the robbers. A strong and healthy colony will not allow robbers to enter because they will have sufficient guard-bees at hand. The guards stand round the entrance inside and outside, with their wings raised waiting ready to spring and repel any invader.

Friend and foe are distinguished by their scent. One would think that no foreign bees would be allowed in (and drones of course are free to come and go) but while foreign bees with empty honey-sacs are always driven away, any that have a full load are allowed to enter. This of course applies to bees that have



Section through a comb showing the double-sided arrangement of the cells

lost their way and that not uncommonly happens among bees whose individual colonies are not very different from one another in colouring.

Comb-building begins in the early spring especially at swarming-time. In the case of a wild swarm which settles in some natural hollow the bees have to start making the comb from the beginning. This natural comb is white. Bees start with a few combs, each at different point; they begin these at the top and work downwards building cell on to cell, on such a plan that one-third of the base and two adjacent walls are laid down at the same time.

In this way a single cell is finished in three stages. Adjacent cells have one common cell wall. The base of the cell is always common to two cells for the comb is a double structure, carrying cells on both sides. The cells are nearly horizontal, but they do slope upwards slightly from the central partition. They are so alternated or 'staggered' that on the one side of the partition, the point at which the axial line of the cell meets the base (which is the deepest point) corresponds on the other side of the partition to the junction point of three side walls. Because of this staggering the combined thickness of the two sides is only a little over three quarters of an inch (22 millimetres) though the two single cells on either side show a maximum depth of just under half an inch (12 mm).

The ground-plan of the honey-comb is hexagonal. This shape is well-adapted to take both the rounded abdomen of the queen as she lays the eggs, and the rounded shape the bee-larva.

It is easy to prove that hexagonal cells make the best use of space by comparison with square or circular ones. With squares there are empty corners and with the circles there are spaces between; besides, circular cells become hexagonal when compressed and the six surfaces of contact are made straight from both sides. We also see this in plant cells which, however, are much more irregular than those of the honey-comb.

There are two sizes of cells: the ordinary small cells are used for rearing the worker-larvae and for storage, the larger for rearing the drones. They measure one-fifth and one-quarter of

an inch respectively. There are thus about four drone cells to five worker cells. As the bee-keeper does not encourage the presence of many drones in the colony, he tries to limit the building of drone-cells. He also seeks to influence the comb-building, for domestic bees have to build on the movable wooden frames with which he furnishes the bee-hive, and not haphazardly. He manages this by hanging his frames the natural distance from one another and providing them with a kind of 'starter' which is a sheet of bees-wax fixed in the middle of each frame. This wax-foundation has the pattern of the worker-cells already stamped out on its surface.

Bees generally build out the cells to the size that has been started for them, though the building of drone-comb is not altogether suppressed. The workers may tear down ordinary cells to satisfy a craving for drone-cells. New comb is light-coloured, mostly yellow from the 'foundation'; it becomes darker and darker from the larval skins and excrement, but it can be used for years. The bee-keeper finally disposes of the old comb and in spring-time, when the bees feel the greatest urge to build, he hangs a new 'foundation' in the hive. For every pound of wax used for building, bees consume 2 ¼ lbs. of honey.

The Foraging Bees

As we have said, foraging activities begin twenty-one days after the bee has emerged from her cell. From now on, they keep to this task for the rest of their lives, which according to the calculation of one research worker, lasts only about four or five weeks. Not a few bees fall victims to the dangers of the outside world; they may be blown by the wind into a pond and drowned, or washed into the gutter by a thunder-shower, or they may be eaten by some other creature. The winter-bees, of course, live much longer than the summer ones; they live over the time when there is no brood, that is from September until March and then bring up the new generation in the spring.

We realise the economy of routine in a bee's life, particularly in leaving the dangerous foraging to the last, so that if they should then come to grief, the other duties will already have been fulfilled. Only when all the hive work is finished do the bees take supreme risks. Their routine is indeed instinctive, but not entirely rigid, not like a piece of music on a gramophone record which once set going just runs on to the end; the bee's programme is much more elastic in emergency. Their adaptability of behaviour can be demonstrated by the following experiments.

Two similar hives, only one of which contained a colony, were set up, back to back. When the colony was well accustomed to the place, that is with all the foragers knowing the position of the entrance, the two hives were interchanged. In the empty hive were now placed two brood frames with young brood from the other hive.

In consequence of this change, the foragers now flew into this hive whose entrance was in the familiar situation and which now contained only two brood-frames. In this way the colony was divided, so that one hive contained the foragers and young brood, the other one, only young bees. These two unnatural colonies, however, were able, at least, within a reasonable time, to carry out all necessary work; for bees of a different age-group stepped into the vacant positions. In the hive with the young bees, a number of them became foragers; what is really more astonishing, the hive with the older bees produced some nurses!

This surprising result was only forthcoming after several days, when the experiment had almost been abandoned. For at first the foragers went on with their usual occupation and did not concern themselves with the hungry brood. Then single individuals began to feed them and with the proper gland secretion, too. By dissecting some of these bees, it was found, that in these old bees the functioning of the food-glands had actually been revived.

Thus the instinct of bees is not 'blind'; but how such a detailed re-arrangement of activities comes about, we do not know. We are still very much in the dark about the organisation of the bee-colony. The queen is as much a tool as are the workers;

her egg-production depends on the varied nourishment that she receives. Again, the kind of egg she lays usually depends on the kind of cell the workers have built. As a rule the queen lays unfertilised eggs in the larger drone-cells and fertilised ones in the smaller worker cells.

It seems as if the worker bees originally held the sceptre and we cannot deny them some reasoning or intuition. Whence comes the urge to build? This question demands research; but we must remember that in every organism, including the human body, the most complicated actions are carried out quite automatically.

The foragers collect three kinds of materials, water, pollen and nectar. They also fetch small quantities of propolis, which they scrape off the sticky bud scales. They use this in the hive to close up cracks in the wood, or to cover larger pieces of waste matter that they cannot carry away.

They collect water from the edge of springs, from shallow streams, and swamps; and they can be seen in large numbers drinking at special places, particularly in hot weather or during the brood-season. Nurse-bees need plenty of water, and in the spring, while there is still no nectar, bees also carry water into the hive, to use for thinning down the winter-honey for food. In summer they bring in water and let it evaporate in the hive to lower the temperature, for cooling is all part of the system of temperature-regulation.

It has been proved that bees do actually lower the temperature, as necessary.

On a hot sunny day, a heating-pad was put underneath a hive and the temperature rose to 112° F. except in the brood-nest where the electric measurements never showed a temperature of more than 97° F. This of course was brought about by the bees.

Sometimes water is brought in all day long, for two or more days and stored in the hive, though not in cells as one might imagine but in the honey-sacs of the bees! We must mention that these special reservoir-bees stand passively near the brood-nest, and are quickly filled up by the water carries and then tapped again by the house-bees. The water is also divided among the

Full-grown worker-bee

A Swarm

community, but whether stored by the reservoir-bees or the house-bees it is always mixed with nectar in the honey-sacs.

Of course the really important part of foraging is collecting pollen and nectar. Pollen is the protein food of bees and the pollen grains are rich in it. A bee-colony needs up to 54 lbs. of pollen.

Nectar on the other hand is purely a food that provides energy. Sometines bees collect pollen and nectar at the same time, but the nectar-collectors will return without pollen, while pollen-gatherers seldom return without nectar.

In watching bees at work new questions arise in the mind. How do bees find the right flowers? How do they find their way home?

A bee that has once discovered a particular source of supply always comes back to it; indeed if it is worth while, she brings other bees to the place until it is all used up. Bees will find flowers on a balcony in the midst of a town. They extend their flights according to need even up to distances of two miles.

We have already remarked how constant they are to one kind of flower and if possible they will keep to a particular kind during all their foraging time. Bees are good observers and have a reliable memory.

The Use of the Senses

How do bees recognise flowers? Do they see colours? Do they see shapes? Do they recognise scents? Perhaps these questions seem superfluous, for otherwise why should the flowers be coloured or scented if not to attract insects to visit them? Wind pollinated flowers which do not need insect visitors are often just green and not very noticeable among other plants. Insect pollinated flowers on the other hand, which are mostly large with white or coloured petals, are more conspicuous, and this is generally thought to be for the benefit of the insects.

The colour sense of insects has been scientifically investigated.

Some bees were fed on consecutive days from a glass dish standing on blue cardboard. The bees soon learnt that the blue

colour promised sugar solution. Then a number of pieces of cardboard of different shades of grey were laid out on the table with a single blue one as well. An empty glass dish was placed on each one. The bees flew straight on to the blue colour and settled on the dish belonging to it, seeking and rummaging around in it as if they could not understand its being empty. This experiment was repeated, with the pieces of cardboard changed about so that the blue one was always in a different place.

The bees trained on the blue colour always looked for the sugar solution in the dish on the blue card, and it is clear that they recognised the colour and distinguished it from the grey shades of similar tone.

This experiment was tried afresh with each colour and it was found that bees can be trained on yellow and also in purple. On the other hand they cannot distinguish red from black or grey. Bees are blind to red, which shows that their colour spectrum is the opposite of ours being in their case shortened at the lower end and lengthened at the upper end: for, as has been shown, bees can distinguish ultra-violet light, which is a colour that we ourselves cannot see.

Corresponding to this they also distinguish a colour 'complementary' to the ultra-violet; now, since it can be demonstrated by physical experiments that most white flowers, such as fruit blossom, absorb the ultra-violet light, we surmise that bees see them as the 'complementary' blue-green colour.

The colour sense of bees is also different from ours in having a poor discrimination for shades of colour. On the whole, we thinks bees only distinguish colours which lie in the range of blue-greens, blues and purples. Now it is interesting to consider the colours of those flowers which are visited particularly by bees. Laburnum, Trefoil, Dandelion and many other 'bee-flowers' are yellow; to our eyes meadow sage, bugle and others are blue. Red flowers are nearly always purple-red and so they probably appear to be blue to the bees.

Some further experiments show that bees do not find their way to flowers by colour alone, but also by shapes.

As in the test with colours, bees were trained on black-and-

white drawings. This training succeeded to some extent. Bees can discriminate between drawings of different flower forms, but it is quite useless to try them on abstract figures like squares, circles, or triangles or letters of the alphabet. Such shapes mean nothing to them. On the other hand bees are very sensitive to the texture of a drawing. It is particularly easy to get them accustomed to striped or spotted surfaces. From this it would appear that the way to nectar in flowers is frequently shown by honey-guides which consist of fine lines or spots.

A sense of smell helps bees to distinguish any particular kind of flower. This sense in bees is nearly as good as in Man as further experiments concerning different scents showed. Some wedge-shaped boxes with a sloping edge eight inches long were put in a row each with an entrance hole and every little box was provided with a scented flower or tropical perfume invisible from outside.

When the bees became accustomed to find a sugar solution in one box with its distinctive smell they could thereafter easily find its place in the row, because they had only to fly below the holes in order to recognise the scent. Bees do not notice scents at a distance, but close at hand they will quickly recognise a flower by its scent.

Bees that have been so trained on scents have established the fact that the organ of smell is actually situated on the feelers. For when their feelers have been covered with a thin coating of shellac, they have been no longer able to find their way to the box despite their training.

Simultaneous training on colour and smell, with control experiments, in which the colour-training has been combined with other scents, and the scent-training with other odours,have shown that bees trust more to smell than to colour. In practice bees go by colour at a distance and by smell at close quarters.

With regard to the kinds of flowers, bees also remember the place where they have found them. They carry away with them the impression of the colour when they fly away, and of the site when they fly back, on making another circuit.

Their sense of smell is used for recognising not only flowers

but also bees of the same colony. It is this sense that leads the bees to the queen at swarming-time. If the swarm is being settled in a new hive, several bees stand in front of the entrance of their new home and 'waggle', that is they stand with their abdomen slightly raised and waft the smell of the colony into the air with a swirling motion of the wings.

This smell of the colony is produced by a perspiration, for every bee has a scent-gland on its back in the fold between the last but one and the last segment of the abdomen, and it is stimulated by 'waggling'. By this means they attract the notice of their companions; it may be done to bring them to the new home, or perhaps to give them news of a source of food.

The way in which bees give one another directions about food supplies, however, deserves a chapter to itself.

Sense of Time

Among other things bees have a sense of time. This conclusion followed almost of itself when in the course of normal laboratory procedure some experiments with bees were carried out at the same time every day. These experiments were mainly concerned with the feeding of a group, and then it became manifest that bees visited the research table only at this time.

Once this had been noticed, the bees were trained to take their food only at certain hours, which were 9 o'clock in the morning, or 3 o'clock in the afternoon. In a short while the bees had learnt the hour and never arrived more than five minutes early to look around.

Then the exercise was made more difficult. Could the bees remember more than one time at once? Yes. They were successfully trained to come at two different times. They even managed a drill of coming three, or four, then five times a day. When it came to six times, only some of the bees were able to do it, and seven times a day meant 'all day' to them.

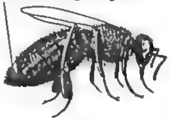
Doubtless this sense is useful to bees since flowers do not secrete nectar all day long or at any rate not so much of it all the

time. Thus bees can learn when the flowers have most nectar and they need only go out foraging at these times; hence they can use the rest of the day for other occupations.

That bees could be made to learn different times in this way is a less surprising feat of 'memory' as such, compared with the fact that the bees remember an appointed hour.

Do the bees note the position of the sun? Have they some internal clock? It would seem that they have! For the trained bees kept to their timing when they were put in a closed house, or even in a part of a mine, under artificial light.

The finest experiment has yet to be made to clear up the question as to whether this sense of time is decided by the position of the sun, that is by the local time, or whether it is due to a constant twenty-four hour rhythm of the body. The experiment would consist of taking a bee hive, whose members were trained in timing, in an aeroplane so many degrees east or west that the local time at the new station would be considerably different from that at the earlier one. Then it could be determined whether the trained bees would fly to the research table according to the new or the former time.

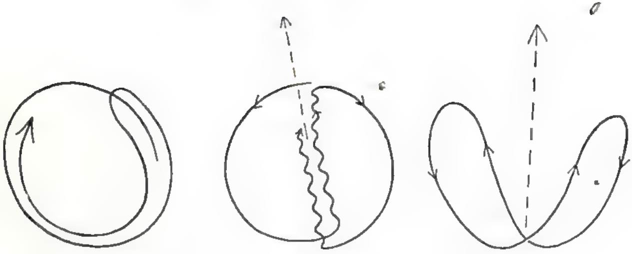


Position of scent-organ

Bees are not alone in possessing a time sense; on the contrary many other creatures have it also.

The 'Language' of Bees

Many bee-keepers are inclined to believe, that bees, like Man, communicate with one another by sound and hearing. They hold this opinion because they themselves are able to deduce a variety of things from the humming note of bees in a hive. For instance, a happy, healthy colony has a different note from that of a weak or queenless one. We can tell at once if a bee is angry or in a stinging mood by the sound it makes. Sometimes we notice that when this desire to sting takes hold of a bee that has perhaps been



'Round dance' *'Tail-wagging dance'* *'Sickle dance'*

carelessly handled, the other bees are infected with the same desire. We come to the conclusion, therefore, that bees do really hear and register sounds. There is also the case of the rival queens, as we have already mentioned, when they make the 'tu–tu–tu' and 'quak' noises.

That bees have an organ of hearing is thus suspected, but it has not been established with certainty. In contrast to this however, more and more is becoming known about the 'sign-language' of bees.

If a bee finds our honey-dish on the breakfast table, we are soon visited by other bees of the same kind and we rightly conclude that bees are able to tell one another about our honey. In confirmation of this we find that all the visiting bees come from the same hive as the first discoverer. To make quite sure we must make use of the observation-hive again.

Near this hive we put out some sugar solution on the laboratory bench, and as they visit the dish, we mark all comers on the back with a white spot. Then we observe their behaviour on their return to the hive.

On arrival, they first give some of their sugar solution to one or more of the hive bees, and then, wherever they happen to be on the comb, they begin a little 'dance' by running round in a circle. When they come back to the starting-point they turn round and do it over again. Quite soon some of the other bees

become aware of the dancer by her pushing them out of her way, and they begin to follow her in the 'round dance', trace the movement with their feelers and follow her to the source of food. Then the horde of bees appearing on our table becomes greater and greater. The 'round dance' has sounded an alert.

How do the newly-arrived bees find the laboratory bench, for they could not manage to fly so closely behind the pioneer that they could keep her in sight? If the food dish is near the hive, it can naturally be found more easily than if it were many hundred yards or a mile away. The remarkable thing is that the bees that have had the news do not take a longer time to find distant or hidden places than the bees that have been there already. It seems as if bees can really acquire an exact idea of where a place is. That is actually the case, incredible as it appears to us.

The 'round dance', which we have just described is used to give information about nearer sources which (according to von Frisch whose work we are following) are within a radius of fifty yards from the hive. For this range bees can give no more exact information about the place: but as regards a natural source of nectar, bees do bring back the smell of the flowers they have visited, as a guide. It has been found that the fine-branched hairs are used as special individual scent-carriers. Now, if a 'dancing' bee carries the scent of lime-blossom, for instance, then the other foragers, which have been enlisted by the dance, go to seek all the flowering lime-trees in the neighbourhood of the hive—a really suitable procedure—for it is very probable that all the lime-trees will be flowing with nectar at more or less the same time.

A bee-keeper can draw the attention of his bees to important sources which they may miss, as for example the inconspicious flowers of the vine, in this way: he dips a bunch of the flowers in a sugar solution which he afterwards places in the hive. The bees quickly go and look for the corresponding scent in the neighbourhood and discover the vineyard that they had overlooked.

Bees not only bring the scent of plants with them when they wish to attract the attention of their companions, for when they are out in the field they are able to give off a smell of their own.

The forager who finds a source of food, having aroused her companions, flies back as before and opening her scent-gland, permeates the air with the smell.

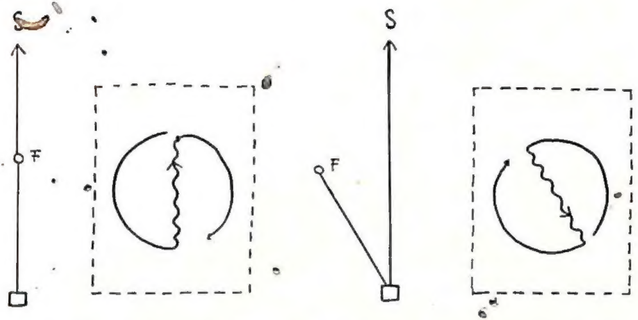
For sources at greater distances, bees on their return do a different dance, by means of which they give the direction and the distance at the same time. This is the 'tail-wagging dance' and applies particularly to distances of over 100 yards. The bee first runs round the comb in a semi-circle, and turns round across the diameter; then she begins again with the other half of the circle, returning to her starting point. The farther away the place is from home, the slower she goes. While she is on the straight run, she moves her abdomen to and fro and the quicker she does it, the farther is the distance. These movements follow such a precision, that an observer with a watch in his hand can calculate the distance correctly himself.

The direction is given by the position on the comb of the waggling path. Of course, this is directly possible only if the bees dance on horizontal surfaces, and, at the same time, are able to see the sun – as on the alighting board. In this way they orientate themselves according to the position of the sun and lay out the direction of the source with reference to this.

However, we must remember that the combs, on which the 'enlistment' dances mostly take place, are vertical. On these the position of the sun in transferred to the perpendicular and then

Branched hairs of the bee

the direction of the waggling-path indicates the direction of the source in relation to the sun. Every deviation from the sun's direction is repesented by the bees as a deviation from the vertical on the corresponding side and at the correct angle. If the source lies straight toward the sun, then the dancing bee lays out the



During the tail-wagging dance on the comb the position of the sun is indicated by the perpendicular

semi-circle, so that during the 'waggling' the direction is straight upwards: if it is away from the sun the bee runs downwards during the waggling. In any other direction, the waggling-path makes an angle bearing left or right from the vertical.

For expressing distances of 50–100 yards, Professor von Frisch has established that there are 'intermediates' between the 'round dance' and the 'tail-wagging dance'. Control experiments on the bee-language in Switzerland and Holland proved that in these countries the 'round dance' was, on the whole, only used for near sources. For distances of 14–20 yards bees show the direction of the source but not the distance; in such cases they run in a sickle-shaped figure of eight, in which the beginning of the sickle gives the direction of the source in relation to the sun. For distances of 100 yards bees again do the 'tail-wagging dance'. Whether the sickle dance is characteristic of only certain strains of bees, is not yet known.

We know already that bees do actually orientate themselves according to the sun and also that in the course of the day they alter the direction of their dance correspondingly when recruiting foragers for some rich source of food. There is another small

experiment which confirms this: if one catches a bee and puts it into a dark box for a few hours and then lets it out, it will go looking for the hive in the wrong direction, indeed, in a direction proportional to the change in position of the sun. It seems extraordinary that bees do not need to see the sun in order to orientate themselves by it.

Because the light from a blue sky is partly polarised (that means that the light-waves are combed out, as hair might be, and vibrate predominantly in one plane) we must assume that the bee's eye can distinguish the polarisation and makes use of this perception for orientation. The planes of polarisation in which the light from the blue sky vibrates are dependant on the sun's position and they are different in different parts of the sky.

In order to test whether bees really use polarised light for orientation, experiments were made with bees using horizontal combs. The little creatures received the light through a thin filter, which only let polarised light through. When this polarising filter was slowly rotated, the bees, one and all changed the direction of their dance.

This, then, is the equipment and endowment of the bees. They are able to distinguish different kinds of flowers, by form and scent; they know the time when these various flowers give most nectar. They give each other information about sources of food, with exact instructions as to distance and direction. Certain of their companions watch the demonstration, understand what is meant and fly off to the given place. They carry a reserve of food in their honey-sacs, corresponding to their needs for the distance they have to fly: for long distances, for places up a mountain-side, for strength against a wind or when only a slight exertion is in prospect.

More or fewer bees follow the enlistment call, according to the intensity of the dance. This, again depends on how much may be expected from any given source, how concentrated the nectar is and how great is the need for food in the colony. A hungry colony will dance for smaller quantities of nectar or for a less concentrated supply, than a well fed colony with a good storehouse.

The community life of bees manifests a higher state of unity, an organisation, which is ruled by means of a division of labour and a specialisation in its individual members, and within which all the activities are promoted with intelligence.

The laws which operate in the bee-community may be applied not only to bees but to the world in general. It is a question of a social code to which all nature, including Man, is subject. Nature knows no masses, rather in her, every multitude is made up of individuals. We have only to think of the multicellular organisms as cell-communities with specialised tissues and organs, or of the animal herds in varying degrees of socialisation.

The tendency to unite a number of members into a higher organisation, makes the individual member a part of a whole. The cells of our tissues are merely constituent parts of the body: the bees mere instruments of the colony. They can no longer live alone. Will the citizen become a mere cog in the state machine?

The grand social problem of the Human state, the solution of which lifts him far above the Insect state, is this: to be a member of a greater whole but to keep the entity of the individual member.

Table of Contents